Dissipative Models: Notes toward Design Method

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In this discussion, I pursue a relationship with the environment embodying the forms of diffusion and dissipation. Seeking essential qualities of emplacement affording subtle phenomena and expanded physiology and measured by mutual relationships of exchange, I will try to articulate a manifesto for architectural design that offers near-living qualities. Rather than polarized working methods that follow only centrally controlled or opposing emergent, incremental models of organization, the fields of the method demonstrated here oscillate. An undulating, quasiperiodic method is evoked by the forms embedded within the projects illustrated here. Deliberate ambivalence is inherent to the approach, yielding qualities where things convulse and stutter in emerging vitality. This personal approach results in shifting boundaries that fluctuate between hard facts and hopeful fictions for exploring the future.

Ilya Prigogine, the great twentieth century physicist, proposed dissipation as a key term for understanding how materials could interact in a constantly evolving and self-organizing world.[1] Prigogine's thought has special value for architectural design, offering a dramatic contrast to embedded traditions. Western architecture has, for the past two millennia, been dominated by paradigms of durability, clarity and stability, enunciated by the first-century Roman Vitruvius in his famous paradigm of 'firmitas'. Vitruvian design education has in turn tended to preserve the ruling philosophy of his Greek predecessor, the philosopher Plato, whose maxims encouraged architecture to harmonize with the natural foundations of the world by following elegant reductions of primary geometry.[2] Applied to architecture, the reductive geometry of Plato's pure circles and simplified crystalline perimeters tends to favour the minimum possible envelope and the maximum possible territory enclosing interior territory. Inspiring such design, pure, reductive geometries can readily be seen within many aspects of natural form finding, exemplified by the space of dew drops and rain drops.[3] Yet the reductive form language that guides such efficiency also makes a mechanism for resisting interaction. The sphere of a raindrop is indeed a reductive machine that rejects interaction. The surface tension of the meniscus encircling a drop of rain pulls inward, and the result is a kind of optimum where the least possible exposing surface encloses the greatest possible mass within. In proportion to its interior volume, there can be no less surface for interaction than that of a sphere. The potency of that equation can hardly be overestimated in its influence on the practice of design.

Similar equations guide the design of a fort that protects, a bullet that pierces, or a bathysphere that can fight the radical forces of the deep. As if guided by a moral compass founded on equations of distillation and purity, western traditions of architecture have tended to value these kinds of pure forms.[4] The resulting architecture tends to seek strength and stability, resisting disruption. Yet why need we assume that the perfectly balanced optimum of a spherical drop of rain is obviously better than the alternate optimum offered by energy-shedding delicate outward-reaching branching spines that radiate from a frozen snowflake? Why, when we think of the myriad of forms that the natural world has offered, should we prefer closed, pure, gloss-faced cubes and spheres to tangled, dissipating masses of fertile soil?

The reductive form-languages of Platonic solids achieve maximum possible territory and maximum possible inertia by minimizing their exposure to their surroundings.[5] Such forms can be effective in a cold climate that requires retention of energy. However, cooling requires the opposite. The opposite of a spherical raindrop appears in the form of frost crystals and snowflakes. Snowflakes epitomize dissipation, optimizing release through an efflorescence of exchange with constantly-unfolding bifurcations determining unique configurations as their thermal reactions expand. Such a form offers a strategy for a diffusive architecture in which surfaces are devoted to the maximum possible intensity and resonance with their surroundings. In turn, following Prigogine, the series of installations and assemblies documented within this paper explore the opposite of reductive spheres and unified crystals. This diffusive architecture pursues qualities similar to those found in veils of smoke billowing at the outer reaches of a fire, the barred, braided fields of clouds; torrents of spiralling liquids; mineral felts efflorescing within an osmotic cell reaction. Such sources are characterized by resonance, flux, and open boundaries lying far from equilibrium.

Gases, Fluids And Membranes

In the natural world, complex systems undergo constant states of perturbation, which generate disequilibrium. Uniformly organized materials can ‘bifurcate’ and take alternative potential forms reacting to changes in energy. Simple fluids affected by a change in thermal energy can dissipate to a new state through thermal conduction, moving through states far from equilibrium.[6] Prigogine offers the example of a snowflake as an exemplary dissipative form where “small vibrations around regularly arranged spatial positions… may lie at the vertices of a cube, or the vertices of a regular hexagonal prism and the centers of their hexagonal bases… a case of equilibrium-mediated emergence of order belonging to the class of phase transitions, an important class of natural phenomena that are largely responsible for the polymorphism of matter […].”[7]

Following the need of sheltering enclosures to alternately retain and shed heat, the kind of diffusive form-language embodied within snowflakes offer a paradigm of involvement with their surroundings. Rather than prioritizing enclosed territory and maximum defense, a form like that of a snowflake seems instead to seek a maximum of involvement through its expanded perimeters. Such forms might instruct the design of new batteries, or perhaps can make more efficient bio-generators modeled after the reticulated interior membranes of mitochondria in human cells. By increasing exposure and engagement with the world, such radical exfoliation can also offer a paradigm for building design. At the scale of architecture, such principles might offer alternatives to the conception of enclosing walls and roof surface, reconceiving those surfaces as deeply reticulated heat sinks, and as layered interwoven membrane curtains that modulate the boundaries between inner and outer environments. A new form language of maximization and engagement implies that design may in turn embrace a renewed kind of stewardship.[8] Such a role replaces the sense of a stripped, Platonic horizon with a soil-like generation of fertile material involvement with the world.

Following Prigogine’s conceptions, air, gas and fluid can act as design media for architecture. The American mechanical engineer Michelle Addington suggests how energy flows around the body and buildings can be addressed in thermodynamic exchanges, exposing the dynamic of convective plumes around each of us and extending this dynamic into architectural scales.[9] Rather than regarding the air as a void, this approach implies that air is an addressable medium for designers. In contrast to prevailing Modern conceptions of space as a neutralized void, the matrix lying between objects may be seen as populated and structured. This sense of effusive matter also extends to the cell. The US-based cancer research of Dr. Donald Ingber has revealed structural systems occurring within the fluid realm of the cytoplasm, structured in ways that invite manipulation by designers.[10] Ingber’s research has demonstrated how the fluid structure of cytoplasm contains interactions between two protein modes: myocin, organized in microtubules offering compression, and actin, working as tensile structures, operating together in a tensegrity grid structuring the viscous medium.

The American zoologist Steven Vogel's seminal research on the structural forms of organisms and their relation to the mechanics of moving fluids illustrates how dynamic forms can lead to highly effective adaptations. The design of organisms responding to drag, flow and lift offers adaptive efficiency. Leaves, exposed to high winds, reconfigure by rolling into conical forms, decreasing their drag.[11] Plants can form themselves into shapes that interact with local air flows to act as pollen traps.[12] The physical adaptations observed in natural forms offer solutions for form-flexible architecture that exists in changing environments. These combined effects could be conceived as a kind of churn that fertilizes relationships between occupants and the environment. The bidirectional exchange between instalment and ecosystem offers a means of constructing new frameworks to build hybrid structures that can mature into more hospitable bionetworks.

Extending the formal structures studied by Vogel and Ingber into the dynamic realm of chemical reactions, artificial life researchers Rachel Armstrong and Martin Hanczyc are part of a movement working with new protocells – prototype cells – exposing the ways designers can work with skin-making mechanisms and carbon-fixing mechanisms.[13] A formation developed by Armstrong and Hanczyc includes a version of a Traube cell, a chemical formulation originally modeled in the nineteenth century as an analysis of the behaviour of living amoebas. Their recapitulation of this study features a delicate copper salt suspended between varying oil densities that permit delicate formations to appear, resulting in the blooming of a mineral felt, powered by osmotic forces pumping solution around a copper sulphate fluid core (figure 1). The dynamic organizations revealed by Prigogine and related researchers invites architectural design to move from the Vitruvian idea of a static world into the dynamic form of a metabolism.

Projects and Methods

Following diffusive form-language, a steadily evolving series of collaborative projects have been developed by the North American and European collaborations of the Living Architecture Systems Group. Recent projects have employed layered systems integrating lightweight scaffolds, simple chemical metabolisms, kinetic mechanisms and distributed computational controls. Structures have tended to be lightweight and ephemeral, organized as resilient textile matrices. The work starts by setting out crystalline forms following diagrids and textile meshworks in order to make lightweight, resonant

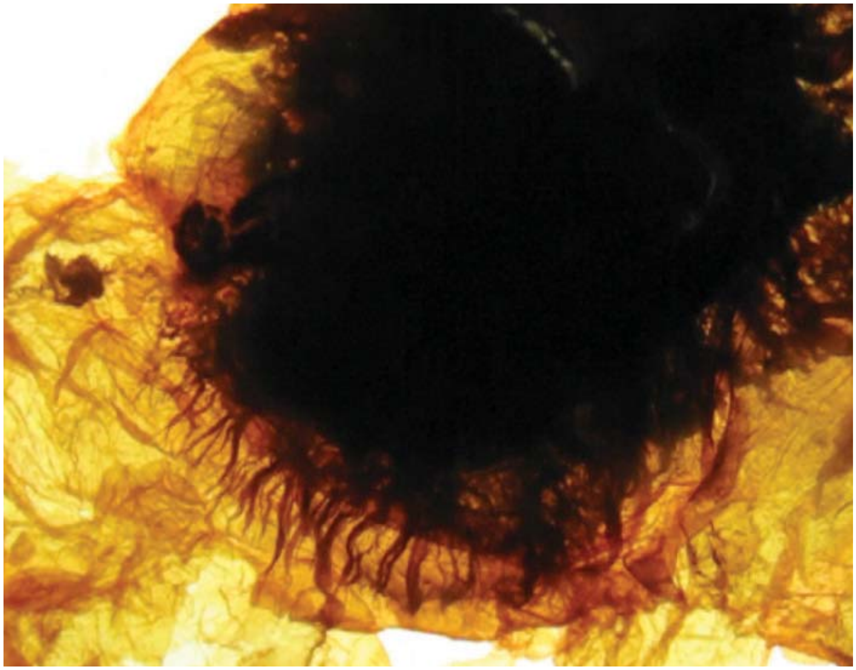

Figure 1 Traube protocells developed for Hylozoic Ground, (Venice Architecture Biennale, Italy, 2010) exhibit osmotic pumping of delicate ferrous membranes, which are formed around copper sulphate vesicles suspended within varying densities of oil.

scaffolds. Flexible lightweight formations are overlaid with microprocessor systems. Kinetic responses are orchestrated by arrayed actuators and sensors, producing turbulent responses that ripple outward (figure 2). Sheet-material derivations expand definitions of space by taking the notion of natural concepts like soil and transforming them into suspended interlinking clouds. In response to human presence, the installation can produce contractile movements, clutching and pulling. Geometries ordering the interlinking structural components used to construct these fields have included quasiperiodic systems where clusters and local arrays can multiply and effloresce, supporting transitions in their interrelationships. A recent stage of development has involved construction of diffusive metabolisms containing protocol liquid reactions creating felt-like chemical skins. This integrated chemistry suggests that buildings could be designed to grow and renew themselves.

Each element within such an environment is gentle, exerting a small response, yet because they are chained together in the hundreds and sometimes the thousands, quite substantial crowd-like responses may occur, suggesting weakly emergent laws of organization. These elements call to mind Prigogine's formulation of systems composed of lattices of identical variables interacting with each other in an environment, where activity from each element is transmitted to its neighbours, in turn affecting the internal state of its "outputting" neighbours leading to emerging properties.[14] In Hylozoic Ground, the individual elements are generated in large arrays where a hyperbolic meshwork stands above the ground making a robust force-shedding structural system with peaks and valleys of doubly curved surfaces. Hovering filters pass convective plumes through them and contain metabolic chemistry that processes and generates new mineral skins by fixing dissolved carbon dioxide from the atmosphere. The bladders, traps and glands seen within these works form soil-like elements. The computation seen here is simple: individual elements chained together produce action akin to a chorus of crickets, or a swarm of insects, or perhaps the opening and closing of polyps in a coral reef. Shift-registers in recent generations of the custom digital control system provide a means of addressing many masses of actuators while using modest micro processing power as the system marches through data sets.

Changing scale in recent work is collaboration in fashion, starting to contribute to the sense of an expanded physiology in literal ways. Iris van Herpen's Amsterdam-based studio has developed clothing that offers a radical intimacy where the skin seems to be rendered as one boundary amongst many. Recent collaboration with Van Herpen[15] includes three dimensional lace made of silicon and impact resistant acrylic. In the recent Voltage series (figures 3), individual components derived from architectural systems were reconceived in miniature form. The layers of this hybrid clothing encourage plumes of air to rise. Fabrics integrate fissured forms configured like leaky heart valves, hovering leaf-like layers that push and pump in gentle waves. A robust silicone meshwork swarms around the body. Individual elements chained together with small silicone tubes make a diagrid of corrugated mesh with diffusive, viscous performance. They make a live performance as they harvest your own energy and ripple around you. Layers lying immediately outside human bodies are organized in octaves of potential exploration, moving into turbulence. Musculature could be considered a mask, and an active fire-like metabolism can be sensed radiating through human skin. A corollary can be seen in a building composed of multiple layers. Traces are pulling at you. You become aware of the impact of your own tread in the world.

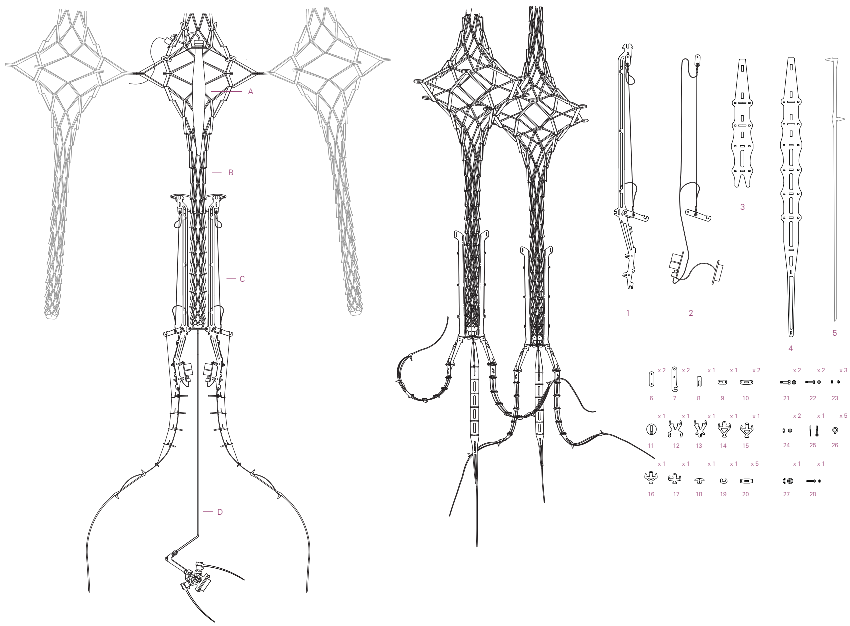

Figure 2 Clusters of flexible meshwork support mounted kinetic tentacles which are activated by optic sensors.

Further Implications: Toward Design of Living Systems

The general principles underlying this work imply mutual relationships and distributed organizations. The hardened boundaries exemplified by Plato's world of spheres and reductive forms might be opened and renewed by form-languages that pursue intense involvement and exchange.[16] This implies a mutual kind of relationship between human occupants and their surrounding environments. In turn, it suggests a craft of designing with materials conceived as filters that can expand human influence while at the same time expanding the influence of the world in an oscillating register: catching, harvesting, pulling and pushing. While personal boundaries can readily be found as functions of central systems – brain, and spine, and hearts define cores that we know well – parallel to those cores lie bundles of ganglia in our elbows or in our sternum and pineal. Neural matter is riddled throughout our bodies, making a series of overlapping networks. Much of our consciousness is bound up in loops and reflexes that happen at the outer edges of cognition. Such a model working internally could be expanded outward. In such a layered space, we could build up a deeply layered, deeply fissure set of relationships in which there are multiple sensitive boundaries. We might be able to build up in a sense of fertility reconstructing a kind of a soil and ground. We could measure values within that constructed ground by measuring resonance. Such a method suggests that the practice of architecture can move closer to the craft of creating living systems.

Figure 3 Finely detailed flexible meshwork structures and translucent fronds form the outer layers of Iris Van Herpen's Voltage collection (Voltage, Haute Couture, Paris, 2013).

For twenty-five hundred years, Western artists and designers have been writing about emulating life. The imagery and forms from this tradition show potent hope for inanimate forms of craft and art coming alive. Yet the speech and evocations of visual art and architecture have often treated 'life' as a kind of boundary defined by separation and distance from human craft. The symbolism that evokes life has been maintained by distinguishing human artifice from the viable organisms of nature. The discipline of architecture seems to have been especially emphatic in maintaining this divide. Architecture seems a counterform to nature, staying deliberately distinct from the living world, preferring instead the role of a stripped stage that supports the living world by means of clear restraint. Perhaps that kind of separation has a moral kind of imperative, avoiding trespass. Yet the distinct progress of science and technology in recent decades invites a change to this strategy of restraint. The achievement of comprehensive information within the human genome project,[17] the accomplishment of potent learning functions in computational control, and the increasing fluency in programming physical materials and projecting complex-system ecological modeling[18] can conspire to demonstrate that living systems no longer need be maintained as a sacrament separate from human intervention. The ability to see our traces and to understand dimensions of the impact with which we thread forms an ethical key to this change. Emerging from the distancing functions of reverence into a new phase of stewardship, living systems can now occupy the space of architectural design.

The qualities of this work offer an alternative to reductive, purifying qualities that have tended to dominate traditions within Western architecture. The morphology described here stands distinctly against prevailing Modern preference for stripped, minimal stages devoted to autonomous freedom. The formal language of this design method instead pursues culpable involvement.[19] Rather than polarized working methods that follow only centrally controlled or opposing emergent, incremental models of organization, the fields of this working method oscillate. Deliberate ambivalence is inherent to the approach, yielding qualities where things convulse and stutter in emerging vitality, characterized by mutual relationships of exchange with surrounding environments. This study opposes Plato's idea of a sphere, the kind of evidently beautiful form embodied by a raindrop. While such a form might claim to be efficient and responsible by reducing consumption, this principle, guiding current minimalism, speaks arguably more of mortality than of fertility. In human culture, spheres can speak of violence and of territorial claims. Instead of such reductive forms I have suggested that snowflakes offer potent form-language that could guide emerging architecture.

In the footsteps of Prigogine, the diffusive, dissipative form-language described here offers a strategy for constructing fertile new architecture. The form-langauge discussion within this approach attempts to open up new spaces bursting with novel potential. The 'mazimizing' interface implied by Ilya Prigogine's conception can guide a fertile generation of architectural design.

Endnotes

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Philip Beesley, MRAIC OAA RCA, is a practicing visual artist, architect, and Professor in Architecture at the University of Waterloo and Professor of Digital Design and Architecture & Urbanism at the European Graduate School. Beesley's work is widely cited in contemporary art and architecture, focused on the rapidly expanding technology and culture of responsive and interactive systems.

He was educated in visual art at Queen's University, in technology at Humber College, and in architecture at the University of Toronto. He serves as the Director for the Living Architecture Systems Group, and as Director for Riverside Architectural Press. His Toronto-based practice Philip Beesley Architect Inc. operates in partnership with the Europe-based practice Pucher Seifert and the Waterloo-based Adaptive Systems Group, and in numerous other collaborations. The studio's methods incorporate industrial design, digital prototyping, and mechatronics engineering. Beesley frequently collaborates with artists, scientists and engineers. Recent projects include a series of hybrid fabrics developed with Atelier Iris van Herpen, curiosity-based machine learning environments developed with Rob Gorbet and Dana Kulić of the Adaptive Systems Group, and synthetic metabolisms developed with Rachel Armstrong of the University of Newcastle. His most recent collaboration with Iris Van Herpen has translated a shared sensibility for subtle materials, electricity, and chemistry into a collection of highly complex and diverse textile and haute couture collections.

His research focuses on responsive and distributed architectural environments and interactive systems, flexible lightweight structures integrating kinetic functions, microprocessing, sensor and actuator systems, with particular focus on digital fabrication methods and sheet-material derivations. Beesley has authored and edited sixteen books and proceedings, and has appeared on the cover of Artificial Life (MIT), LEONARDO and AD journals. Features include national CBC news, Vogue, WIRED, and a series of TED talks. His work was selected to represent Canada at the 2010 Venice Biennale for Architecture, and has received distinctions including the Prix de Rome, VIDA 11.0, FEIDAD, Azure AZ, and Architizer A+.